

Greenhouse Gas Emissions From Indirect Land Use Change

**CARB LCFS Working Group 3
Sacramento, CA
January 17, 2008**

**Michael O'Hare
Professor, Goldman School of Public Policy
University of California, Berkeley**



Overview

- Ethanol from crop plants will induce additional cultivation somewhere in the world, or reduce grain consumption as food.
- Three kinds of change will occur:
 - People will eat less, or eat less meat.
 - Agriculture will become more intensive
 - Land will be converted from something else to crops
- The second and third release GHG not counted in the LFC analysis of the ethanol crop itself
 - As far as we can tell now, these releases are very large (research is still scanty).
 - The smallest estimates available for land use change alone put corn ethanol and all biodiesels well above gasoline in unit GWP.
- Simply increasing corn ethanol content in vehicle fuel should not be considered the “typical” means of compliance with LCFS.

Don't bet the farm on these numbers

- This presentation offers some rough numerical examples which will be replaced in the coming months by better analyses.
 - UC Davis (Mark Delucchi)
 - U.S.EPA (Office of Transportation and Air Quality)
 - Princeton (Tim Searchinger)
 - others we don't know about?
- There is a great deal of uncertainty in the numbers but within a range all of which has important policy implications
- This presentation is meant to enhance the discussion of the issue, not to resolve it

Note: These are rough estimates, and should be replaced when better estimates are available.

Growing biofuel feedstocks changes land use

- **Direct land use change**

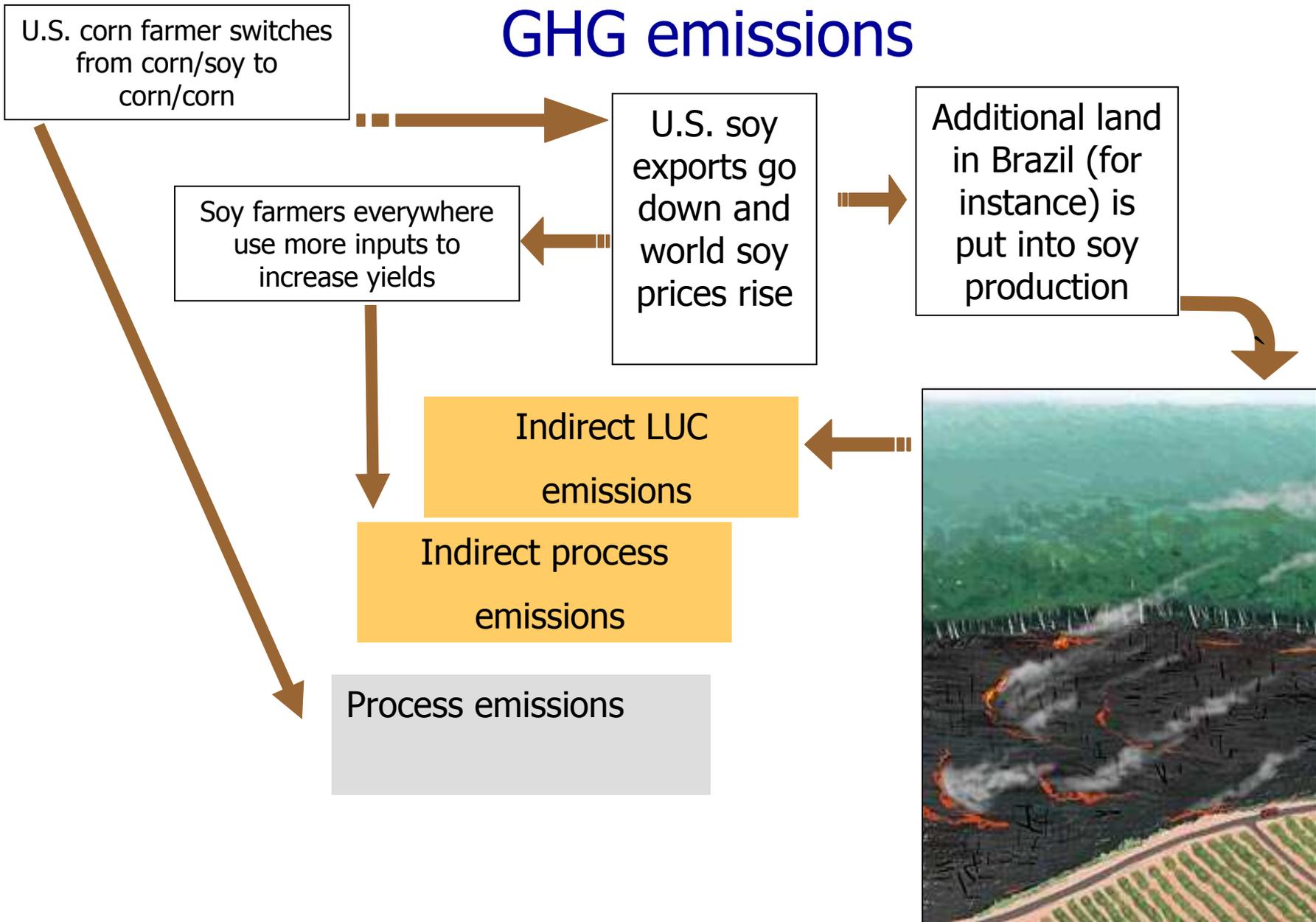
- Land used to grow biofuel feedstocks that used to grow something else (including wild lands)
- Example 1: shift from Conservation Reserve Program (CRP) to corn
- Example 2: shift from corn/soy rotation to continuous corn
- Example 3: shift from grazing to sugarcane (Brazil)

- **Indirect land use change**

- Changes away from the biofuel plantation caused by growing biofuel feedstocks
- Example 2b: deforestation for pasture land (or to grow fodder) to feed cattle that are displaced by cane, or not fed with corn
- Example 3b: deforestation for new soy production to “replace” soy no longer exported by the United States

These are normal outcomes of food, fuel, and land markets

Land use change (LUC) may cause large GHG emissions



Reliable estimates of LUC require economic modeling

- Models must include
 - Feedstock production functions
 - Prices for land and other resources
 - Elasticity estimates for supply and demand
 - The rest of the economy
 - Other countries
- The approach taken here is very simple
 - Assume that one acre of biofuel feedstock production causes exactly one acre of land use conversion elsewhere
 - These estimates are not necessarily a worst case (upper bound)
 - These estimates are *not* reliable, but indicate the scale of the issue.
 - Calculated by Alex Farrell and several graduate students

GHG emissions due to indirect LUC appear to be very large, but are highly uncertain

Direct Emissions*	Gasoline	Midwest Corn Ethanol	CA Ultra Low Sulfur Diesel**	Canola Biodiesel**	Renewable Diesel** (Palm)
g/MJ	94	88	93	32	21
Indirect emissions by fuel and type of LUC***	Corn ethanol - CRP	Corn ethanol - tropical forest	Sugarcane ethanol - tropical forest	Canola biodiesel - tropical forest	Palm diesel - tropical forest
g/MJ	140	540	289	1031	197
Uncertainty: corn ethanol - tropical forest	20-yr, low emission factor	20-yr, mid emission factor	20-yr, high emission factor	100-yr, low emission factor	100-yr, high emission factor
g/MJ	420	540	826	84	165
*(California Alternative Fuels Plan, CEC-600-2007-004-REV)					
** No adjustment for drivetrain efficiency					
*** See posted spreadsheet. Assumes 20 year amortization period, among other things.					

Note: These are rough estimates, to use until better estimates are available.

What's considered in estimates

- One-time CO₂ release from
 - burning or decay of existing biomass on 'new' land,
 - GHG release from land-clearing operation,
divided by years of biofuel production.
- Yield of biofuel from 'new' land
 - Note that this may be more or less than average yields from current operations.
- GHG releases from cultivation
- (GHG releases from more intensive cropping): fertilizer, water, pesticides, cultivation)

If these values are used, most biofuels have *higher* GHG emissions than do fossil fuels

- If corn grown on CRP land is used for ethanol, total lifecycle emissions, including indirect LUC, are
 - $88 + 140 = 228$ g/MJ
 - 2.4 x gasoline
- If replacing corn used for ethanol causes tropical deforestation, total lifecycle emissions, including indirect LUC, are
 - $88 + 540 = 628$ g/MJ
 - Over 6 x gasoline
- Renewable diesel using palm oil has total lifecycle emissions, including indirect LUC, of
 - $21 + 197 = 220$ g/MJ
 - 2.3 x diesel

Note: These are rough estimates that should be replaced when better estimates are available.

These estimates have to be very wrong for better analysis to change the qualitative results.

For these land use changes...		Corn ethanol – tropical forest	Sugarcane ethanol – tropical forest	Canola – tropical forest
the foregoing estimates would have to be this much smaller for these fuels to be equivalent to gasoline		99%	98%	94%

Note: These are rough estimates of the worst case, and should be replaced when better estimates are available.

Some policy implications are clear *despite* the uncertainties

- Deciding how to estimate GHG emissions from indirect LUC will have major implications for the LCFS and AB32
- Deciding if and how to apply GHG emissions from indirect LUC to biofuels historically, and in the future will have major implications
- Further uncertainties in lifecycle GHG emissions require research and policy decisions.
 - Example: other emissions like black carbon, SOX, NOX, etc.
- LCA accounting methods are likely to change in the future
- More R&D is needed

Note: Better LUC estimates are unlikely to change these action implications.

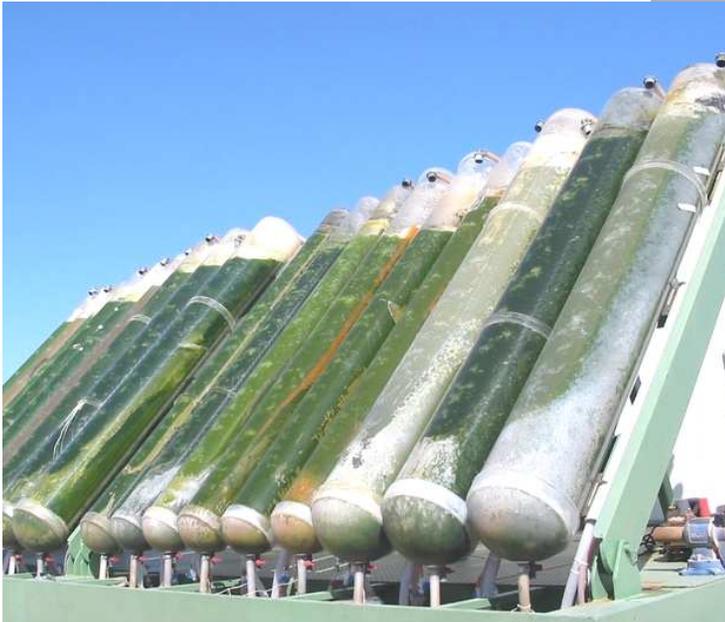
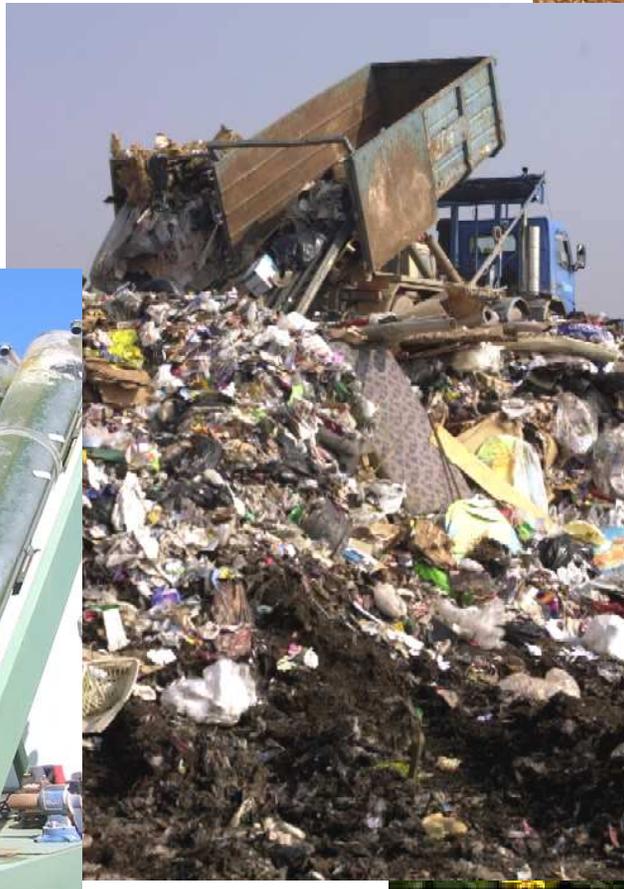
Many possible LCFS compliance strategies remain

- Major improvements in crop-based biofuels
- Replace crop-based biofuels with fossil fuels (?)
 - Will not address AB32 goals
- Replace crop-based biofuels with biofuels that do not cause LUC
 - Wastes, residues, “agricultural integration”, marginal land, algae (?)
- Lower GHG emissions from fossil fuel production
- Electricity
- Hydrogen (generated how?)
- Etc.

Note: Better LUC estimates are unlikely to change these implications.

Advanced biofuel technologies will be needed to produce fuels without causing LUC

- Most biofuel feedstocks that do not cause LUC are cellulosic
- Other feedstocks are even more advanced



Today's biofuel industry has several options

- **Incremental improvements**

- Lower GHG emissions of feedstock production
- More energy efficient biorefineries
- Agricultural innovation and integration
- Biomass energy supply for biorefineries
 - Chippewa Valley Ethanol Co. in Benson, MN
 - Biomass gasifier
- Process integration
 - E3 Biofuels in Meade, NE.
 - Feedlot + Manure Digester + Ethanol plant
- Greatly increased yields (but inputs have GHG effects)

- **Innovations**

- New microbes and processes to produce better fuel molecules
- Upgrades to use cellulosic processes
- Carbon capture and sequestration

Your thoughts?

